

# Electricity consumption and economic growth in ASEAN

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## ABSTRACT

The relationship and causality direction between electricity consumption and economic growth is an important issue in the fields of energy economics and policies towards energy use. Extensive literatures has discussed the issue, but the array of findings provides anything but consensus on either the existence of relations or direction of causality between the variables. This study extends research in this area by studying the long-run and causal relations between economic growth, electricity consumption, labour and capital based on the neo-classical one sector aggregate production technology mode using data of electricity consumption and real GDP for ASEAN from the year 1983 to 2012. The analysis is conducted using advanced panel estimation approaches and found no causality in the short run while in the long-run, the results indicate that there are bidirectional relationship among variables. This study provides supplementary evidences of relationship between electricity consumption and economic growth in ASEAN.

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## 1. Introduction

Energy is essential to human societies and assumed a critical part in economic growth. It has turned into a significant contributor for worldwide economy in the course of the last few decades. According to Dantama et al. (2011), energy affects all aspects of development including social, economic, and even quality of life. In spite of that, energy is also considered as an important element in the industrialization and technology advances (Jumbe, 2004). It was also found that the increased consumption of energy signifies the high economic status of a country, along with its role in fostering the productivity of labour, capital, and other factors of production.

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Energy can be disaggregated into several elements such as oil, gas, electricity, and coal. However, among these types of energy, oil seems to be the most frequently used proxy for energy in the past studies to determine economic growth either by considering the price or the consumption of the energy itself, for example, Masih and Masih (1996), Asafu-Adjaye (2000), Ozturk et al. (2010), Lau et al. (2011), and Dahmardeh et al. (2012). Even though many studies on energy economics use oil as the proxy for energy, electricity is also regarded as an astounding quality energy component because it supports a wide range of products and services that encourage growth (Adom, 2011). Besides, oil is projected as the slowest growing energy for the next 20 years (Finley, 2012). Therefore, many studies had been conducted to search for the best energy to replace oil. In the recent previous years, electricity has gained interest among recent researchers since electricity plays an important role in the economic development (Hu & Lin, 2013). Furthermore, Dorsman et al. (2015) found evidence that electricity consumption and economic growth are positively related. Additionally, its portion in energy consumption is rising quickly as it is comfortable, high in quality, environment-friendly, and a flexible form of energy that could be converted to other energy types.

Electricity is also measured to be associated with the standard of living. Considering the rise in lifestyle, electricity is a vital infrastructural input for economic development. Despite the fact that GDP indicates a country's development level, electricity consumption is also one of the main indicators that reflect the economic level of the countries (Jumbe, 2004). A country's economy growth and its electricity consumption are believed to be connected whether in the short-run or in the long-run. Generally, any changes in electricity consumption are often positively associated with the changes in economic growth (EIA, 2013). Nevertheless, it also acts as the key factor in improving the quality of human's life as well as a key input in the development of the certain sector. (Rosenberg, 1998) and Chaudhry et al. (2012) analyzed the relationship between energy consumption and economic growth in Pakistan based on annual data for the period of 1972-2012. Instead of employing energy as a whole, energy was disaggregated into components such as oil, gas, coal, and electricity. Amongst the energy components, the results showed that electricity was the most significant energy that enhanced the production of goods and services.

### *1.1 Association of Southeast Asian Nations (ASEAN)*

The Association of Southeast Asian Nations or ASEAN, is a collaboration that was established on 8 August 1967, started with the signing of a declaration between 5 countries in Southeast Asia, namely Indonesia, Malaysia, Philippines, Singapore, and Thailand. The declaration is also known as Bangkok Declaration because it was signed in Bangkok, Thailand. Later, the collaboration was also joined by other countries in the region, started with Brunei Darussalam on 8 January 1984, followed by Vietnam on 28 July 1995, Lao, PDR and Myanmar on 23 July 1997, and Cambodia on 30 April 1999. Therefore, ASEAN is a regional organization among ten countries with a target to preserve long-term peace in Southeast Asia and to balance the roles of outside powers in Southeast Asia (Kurlantzick, 2012). ASEAN highlights economic growth, economic development, and social and culture of Southeast Asia countries, and tries to protect the mutual interest by creating regional solidarity and promoting regional peace and stability (Gyngell, 1983).

Over the past two decades, ASEAN has been known as the most open economic region, and the leader of East Asian trade, economic, and security integration. Looking at the growing market of ASEAN, it is expected to be the fourth largest economy by 2050, which means that ASEAN's potential market would be larger than the European Union or North America. Economic giants like United States and China are competing for influence over ASEAN's economic, socio-political, and security issues due to the strategic value own by ASEAN. The strong economic performance has progressively enabled all ten ASEAN countries to achieve significantly higher economic development for the past decades. However, the rapid advancement of ASEAN is roused by the financial crisis of 1997-1998. The crisis had left a huge impact

on ASEAN with most of the member states seriously debilitated on the grounds because the significant part of the investments in ASEAN was moved to China. This was upsetting for the ASEAN countries that depend on investment and export to developed countries and to enhance economic growth, social stability, and international political standing. Starting from that crisis, ASEAN countries have improved their approach and consistently focus on regional integration.

Looking at the strength of the economy and resources, ASEAN is on the right path to be back seen as the future engine of growth in Asia as well as the world. Therefore, identifying and managing the relationship between economic growth and energy consumption is very crucial in understanding the economic growth path in the future and living standard of its population. Based on the analysis of trends data on GDP and electricity consumption for ASEAN for the past three decades, it is apparent that the continuous increase in electricity consumption is quite consistent with GDP. The significant rise in demand and virtual dependence on energy, especially electricity is due to technology driven lifestyles of the twenty-first century, further makes an inquiry into mechanisms linking these key variables a timely one. Further studies on ASEAN as a whole are needed because the characteristics of ASEAN are different from other regions, even varies among ASEAN countries. According to IEA (2015), the inherent differences among ASEAN countries have important implications for the different power systems in terms of markets (pricing, impact of subsidies), governance frameworks (institutions, policies), electricity security (national resources, electrification, emergency), as well as region-wide initiatives, at both individual country and regional levels.

## **2. Literature review**

As mentioned earlier, the study of the relationship between energy consumption and economic growth started with the inspiring research by Kraft and Kraft (1978). They used 1947-1974 economic data of USA to find causality running from GNP to energy consumption. They discovered that increased economic growth leads to increased energy consumption. However, several researchers started to doubt the findings. Hence, the relationship between energy consumption and economic growth has been widely investigated, where some researchers supported the findings while others opposed the finding. Since then, the postulated relationship has been the topic of considerable research in the energy economics literature.

Reviewing the existing literature on economic growth and energy consumption, it is observed that some studies only examined energy and growth relationship. Olayeni(2012) used the aggregate of both energy and income for 12 sub-Sahara African countries and employed the bivariate modeling approach. The outcomes revealed that the growth of some countries could be adversely affected by energy conservation policies while for some other countries, such policies may enhance the countries' growth. However, the bivariate modeling approach applied in this study has been criticized on the ground that it does not allow for evaluation of substitution effect of energy with other economic variables. Lütkepohl (1982) also argued that the outcomes from the bivariate analysis would result in the possibility of omitted variable bias.

Therefore, Dlamini et al. (2013) assumed that by adding a third or fourth variable, the relationship between energy consumption and economic growth could be indirectly affected by these additional variables, which reduces the potential omitted variable biases to occur in the analysis. A previous study by To et al. (2012) included labour, capital, and human capital, in addition to GDP and energy consumption in their investigation on the relationship between GDP and energy consumption in Australia. The outcome of the study indicates a positive, but weak relationship between the two energy consumption and economic growth. Huang et al. (2008), Soytaş and Sari (2009), as well as Payne and Taylor (2010) also applied a multivariate framework by including variables of labour and capital in their regression model to avoid the bias problem. Meanwhile, Masuduzzaman (2013) when investigating the relationship between electricity consumption and economic growth for Bangladesh, reported that most of the existing literature on

electricity consumption and economic growth for Bangladesh had fallen into the omitted variables trap as they examined the energy-growth relationship using bivariate framework model. Therefore, his study included investment as an addition to rectifying the problem. The study indicates that there is an existence of unidirectional causality running from electricity consumption to economic growth in Bangladesh. Narayan and Smyth (2008), who applied the panel data in analyzing the data from 1972 to 2002 for G7 countries found that energy consumption and economic growth were cointegrated. Also, Ciarreta and Zarraga (2010) found the existence of long-term equilibrium relationships between energy consumption and economic growth for 12 European countries, using data from 1970 to 2007 and in the short run, energy consumption was revealed to lead economic growth. Apergis and Payne (2010) who also employed panel data found that there is a presence of both short-run and long-run unidirectional causality from energy consumption to economic growth in OECD countries. In the most recent study by Osigwe and Arawomo(2015) who applied the Error Correction Model framework, theyreached the conclusion stating that there is a relationship between electricity and growth in Ghana, which was also established in the study by Ozer and Mensah (2015).

### 3. Data and methodology

The study used the annual data of 30 years, from 1983 to 2012, where Y, E, L, and K were used to represent economic growth, electricity consumption, labour, and capital, respectively. For the purpose of the analysis, the variables were then transformed into natural logarithms. Data were collected from 10 ASEAN countries namely Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines, Singapore, Thailand, and Vietnam, for the period of 1983 to 2012. The detailed description of all ASEAN countries is shown below:

Table 3.1. Descriptive statistics

Variables	Mean	Std. Dev.	Maximum	Minimum
Y	23.99674	1.676562	26.78149	20.48716
E	22.84352	2.00821	25.84417	18.30729
L	15.96413	1.846298	18.5894	11.27427
K	22.45822	2.001672	25.51007	18.41083
Observations	300	300	300	300

Notes: Y is the real GDP (constant 2005 US\$), E is the electricity consumption (in kilowatts per hour), L is the total labour force and K is the gross capital formation (constant 2005 US\$). Std. Dev. Denotes the Standard Deviation. All the variables are in natural logarithms

The relationship between economic growth, electricity consumption, capital, and labour described in the neo-classical one-sector aggregate production model, suggest that their movement in the long-run may be related. Furthermore, the neo-classical one sector aggregate production technology model proposed by Ghali and El-Sakka (2004) as discussed previously, shows that capital (K) and labour (L) are also variables in the model, that is depicted in Equation 3.1.

$$Y_t = f(K_t, L_t, E_t) \quad (3.1)$$

Taking the differential of Eq. (3.1) and dividing through by the expression below is obtained:

$$\partial Y_t = Y_K \partial K_t + Y_L \partial L_t + Y_E \partial E_t \quad (3.2)$$

where  $Y_{(i)}$  is the partial derivative of  $Y$  with respect to its  $i$ th argument. On dividing Equation (3.2) through and rearranging the resulting expression, the following growth equation is obtained.

$$\dot{Y}_t = a\dot{K}_t b\dot{L}_t c\dot{E}_t \quad (3.3)$$

where a dot on the top of the variable means that the variable is now in the growth rate form. “ $\dot{Y}$ ” is the rate of change of economic growth, “ $K$ ” is the rate of change of capital, “ $L$ ” is the rate of change of labour and “ $E$ ” is the rate of change of electricity consumption. The constant parameters  $a$ ,  $b$ , and  $c$  are the elasticity of economic growth with respect to capital, labour, and electricity consumption, respectively. This study examines the relationship between output and capital, labour, and electricity consumption inputs described by the production function in Equation (3.3), suggesting that their long-run movements may be related.

### 3.1 Construction of references

Panel unit root tests are implemented to look at the level of joining between variables. It has been prescribed as an option for inspecting the causal relationship between energy consumption (electricity) and economic growth (GDP) in a panel structure. This technique is prevalently utilized on the grounds that the asymptotic dissemination is standard ordinary, rather than the non-typical asymptotic circulations (Baltagi, 2004). Panel unit root test is recently one of the most popular tests because of its higher power compared to the unit root tests for individual time series (Adhikari & Chen, 2012). The test for unit roots is conducted using three panel based methodologies proposed by Levin et al. (2002), hence alluded to as LLC. Im et al. (2003) starting here and into the future alluded to as IPS, and Breitung (2000).

The LLC test is the most widely used panel unit root test and it can be written as follows:

$$\Delta y_{it} = \alpha_i + \delta_i y_{it-1} + \sum_{j=1}^{p_i} p_i \Delta y_{it-j} + e_{it} \quad (3.4)$$

where  $\Delta$  is the first difference operator,  $y_{it}$  is the series of observations for country  $i$  for  $t = 1, \dots, T$  time periods. The test has the null hypothesis  $H_0 : \delta_i = \delta = 0$  for all  $i$  against the alternative of  $H_1 : \delta_i = \delta < 0$  for all  $i$ , which presumes that all series are stationary. LLC assumes that  $\delta$  is homogenous across countries based on the  $t$ -barstatistic test. The IPS test is an expansion of the LLC test and is focused around the mean of the individual unit root statistic in the same model utilized as part of the LLC test.

Testing for a unit root is also performed using the IPS panel unit root test as proposed by Im et al. (2003), which is appropriate for balanced panels. Unlike the LLC which makes the assumption that the autoregressive parameters ( $\delta$ ) are homogenous across panels, the IPS test relaxes this assumption. The IPS test allows for heterogeneity in the coefficient of  $\delta$  under the alternative hypothesis. Given the following autoregressive specification as prepared by Apergis and Payne (2010):

$$y_{it} = \rho_i y_{it-1} + \delta_i X_{it} + \varepsilon_{it} \quad (3.5)$$

where  $i=1, \dots, N$  for each country in the panel;  $t=1, \dots, T$  refers to the time period;  $X_{it}$  representing the

exogenous variables in the model, including fixed effects or individual time trend,  $\rho_i$  are the autoregressive coefficients, and  $\varepsilon_{it}$  are the stationary error terms.

Meanwhile, Breitung (2000) proposed a  $t$ -ratio type test statistic for testing a panel unit root. The Breitung panel unit root test has the following form,

$$\gamma_{it} = \alpha_{it} + \sum_{k=1}^{p+1} \beta_{it} x_{it-k} \varepsilon_t \quad (3.6)$$

### 3.3 Panel cointegration tests

For cointegration test, the model is estimated using the ARDL developed by Pesaran and Smith (1995). This study applies the panel ARDL because unlike other techniques such as the Johansen approach, the ARDL method is applicable irrespective of whether the regressors in the model are purely  $I(0)$ , or purely  $I(1)$ , or a mixture of both (Mahran, 2012). Moreover, the ARDL procedure performs better in small or finite samples (as in the present study), in the sense that it gives relatively more robust (efficient) results than other cointegration techniques. For panel analysis, Pesaran et al. (1999) suggest Mean Group (MG) model in order to resolve the bias due to heterogeneous slopes in dynamic panels. The MG estimator, on the other hand, provides the long-run parameters for the panel by making an average of the long-run parameters from ARDL models for individual countries. For instance, as prescribed by Rafindadi and Yusof (2013), if the ARDL model follows,

$$Y_{it} = a_i + \gamma_i Y_{it-1} + \beta_i X_{it} + \varepsilon_{it} \quad (3.7)$$

Here,  $i$  stands for the country where  $i=1, 2, 3, \dots, N$ . then the long run parameter is  $\theta_i$

$$\theta_i = \frac{\beta_i}{1 - \gamma_i} \quad (3.8)$$

and the MG estimators for the whole panel will be given by

$$\hat{\theta} = \frac{1}{N} \sum_{i=1}^N \theta_i \quad (3.9)$$

$$\hat{a} = \frac{1}{N} \sum_{i=1}^N a_i \quad (3.10)$$

The above equations reveal how the model estimates separate regressions for each country and calculate the coefficients as unweighted mean of the estimated coefficients for the individual countries. This does not impose any restriction. It allows for all coefficients to vary and be heterogeneous in the long run and short run. However, for the consistency and validity of this approach, there is a need to have a sufficiently large time-series dimension of the data.

The Pool Mean Group, on the other hand, was applied in order to detect the long and short run association between energy consumption and economic growth, and also to investigate the possible heterogeneous

dynamic issue across countries. The appropriate technique to be used for the analysis of dynamic panels is Autoregressive distributed lag ARDL (p,q) model in the error correction form, and then estimates the model based on the mean group (MG) presented by Pesaran and Smith (1995), and Pooled Mean Group (PMG) estimators developed by Pesaran et al. (1999).

### 3.3 Panel causality tests

Cointegration result does not specify the direction of the causality relation. Therefore, Granger causality test is implemented to establish the direction of panel causality. We adopt panel based error correction model or known as vector error correction model (VECM). This technique uses the two-step process to examine Granger causality in the long-run relationship as proposed by Engle and Granger (1987). The first step is estimating the residuals from the long-run model, and the second step includes fitting the evaluated residuals as a right-hand variable in an element lapse amendment model. The dynamic error correction model utilized is expressed as:

$$\begin{aligned} \Delta LGDP_{it} = & \alpha_y + \beta_y ECT_{it-1} + \gamma_y \Delta LEC_{it-1} + \gamma_y \Delta LEC_{it-2} + \delta_y \Delta LGDP_{it-1} + \\ & \delta_y \Delta LGDP_{it-2} + \delta_y \Delta LK_{it-1} + \delta_y \Delta LK_{it-2} + \delta_y \Delta LL_{it-1} + \\ & \delta_y \Delta LL_{it-2} + \varepsilon_y \end{aligned} \quad (3.11)$$

$$\begin{aligned} \Delta LEC_{it} = & \alpha_e + \beta_e ECT_{it-1} + \gamma_e \Delta LEC_{it-1} + \gamma_e \Delta LEC_{it-2} + \delta_e \Delta LGDP_{it-1} + \\ & \delta_e \Delta LGDP_{it-2} + \delta_e \Delta LK_{it-1} + \delta_e \Delta LK_{it-2} + \delta_e \Delta LL_{it-1} + \\ & \delta_e \Delta LL_{it-2} + \varepsilon_e \end{aligned} \quad (3.12)$$

where  $\Delta$  denotes the difference operator; ECT is the lagged error correction term derived from the long-run cointegrating relationship;  $\beta_y$  and  $\beta_e$  are adjustment coefficients, and  $\varepsilon_y$  and  $\varepsilon_e$  are disturbance terms. The coefficients on ECT demonstrate how rapidly deviations from the long-run equilibrium are dispensed with emulating changes in every variable.

## 4. Findings

Table 4.1. Results of the panel unit root tests

Variables	LLC		IPS		Breitung	
	Level	1st Diff.	Level	1st Diff.	Level	1st Diff.
LnGDP	-4.414 (0.0000)*	-5.678 (0.0000)*	-1.3177 (0.0938)	-6.6553 (0.0000)*	1.8744 (0.9696)	-6.0501 (0.0000)*
LnElectricity	-2.747 (0.0030)*	-6.7917 (0.0000)*	-2.0817 (0.0187)*	-9.1583 (0.0000)*	3.2498 (0.9994)	-7.2529 (0.0000)*
LnLabour	-2.954 (0.0016)*	-3.9804 (0.0000)*	1.4716 (0.9294)	-6.7527 (0.0000)*	4.9327 (1.0000)	-5.3368 (0.0000)*
LnCapital	-1.1758 (0.1198)	-4.5462 (0.0000)*	-2.5117 (0.0060)*	-8.9219 (0.0000)*	0.6102 (0.7291)	-6.5688 (0.0000)*

Notes: \* indicates statistical significance at the 5 percent level. All tests assume asymptotic normality. The lag length is automatic selected using the Akaike Information Criteria. All variables are in natural logarithms (LN).

Firstly, the variables at level are tested to find whether null hypothesis of the unit root can be rejected. LLC test rejects the null hypothesis at 5 percent for LnGDP, LnElectricity, and LnLabour. At the same time, IPS indicates that we can reject the null hypothesis as the probability is less than 5 percent for

LnElectricity and LnCapital. After LnGDP at first difference is tested, all three tests reject the null hypothesis at 5 percent. Meanwhile, Breitung test shows that the null hypothesis of non-stationary for all variables cannot be rejected. However, when the variables at first difference are tested, all tests indicate that the null hypothesis of non-stationary for all variables can be rejected. Generally, the panel unit root test of LLC, IPS, and Breitung show that the variables for all country group are integrated at first difference which means that LnGDP, LnElectricityLnLabour, and LnCapital are integrated at I(1).

Table 4.2. Results of the panel ARDL

Variables		MG Estimation		PMG Estimation		Hausman
		Coef.	P> z	Coef.	P> z	
LR	LnElectricity	-0.0439899	0.876	0.2430381	0.000	Prob>chi2 = 0.6303
	LnLabour	1.917906	0.071	0.8345216	0.000	
	LnCapital	0.0394828	0.831	0.3762088	0.000	
	ECT	-0.2875734	0.000	-0.0736183	0.182	
SR	D.LnElectricity (-1)	0.0950992	0.278	0.11669	0.338	
	D.LnElectricity (-2)	-0.0121825	0.730	0.0110452	0.770	
	D.LnLabour(-1)	-1.298146	0.018	-0.4418238	0.238	
	D.LnCapital(-1)	0.0794527	0.001	0.1022716	0.000	
	Constant	0.6454413	0.728	-0.3012439	0.171	

Note: Estimations are done by using (xtpmg) routine in Stata. The lag structure is ARDL (1, 2, 1, 1), and the order of variables is real GDP, electricity consumption, labour force and real gross fixed capital. All the ASEAN countries, annual data 1983–2012.

As disclosed earlier using Westerlundcointegration test, it was learned that there is a long run relationship among variables in all sample countries group. Table 4.2 reports the estimation results of PMG and MG models for the short (SR) and long term (LR). The Hausman Test is conducted in order to test the hypothesis of the long-run elasticity and homogeneity. Given the results of the Hausman test, it shows that the null hypothesis is not rejected since it is more than 5 percent and thus, PMG is a valid and better estimator than MG. Therefore, the findings from PMG model will be emphasized.

MG estimator seems not to be valid but ECT and D.LnCapital(-1) coefficients are statistically significant in the short run and the long run period. According to PMG estimation, all independent variables coefficients are reported to have long-run contributory on GDP based on the significance at 5 percent level. This result highlights that in the long-run, the influence of electricity consumption, labour, and capital on GDP is positive (LnElectricity = 0.2430381, LnLabour = 0.8345216 and LnCapital = 0.3762088), which means that when the electricity consumption, labour and capital rate increases, GDP rate will also increase. The changes in these variables will have an explicit influence on the GDP in the future.

However, the short-run analysis shows contrasting results. The analysis reveals that all variables have an insignificant impact on GDP, except for LnCapital (-1). This means that electricity consumption and labour have no short-run contributory impacts in fostering economic growth. The error correction coefficient corresponds to the speed of reaching equilibrium in the long run. Since correction coefficient - 0.0736183 was found; the emerging imbalances will be corrected at 7.3% per year. However, the validity



of this finding was not supported by the error correction coefficient, which shows the insignificant result ( $p = 0.182$ ).

In summary, it was discovered that there is a long-run cointegration among all variables, particularly between electricity consumption and economic growth for groups of all countries and developing countries. Therefore, there is evidence that electricity consumption is an important contributing factor to economic growth. The results also indicate that any changes in electricity consumption would bring a significant impact on economic growth in the long-run (Lee and Chang, 2008). Similar results are also found by Mishra et al. (2009), Imran and Siddiqui (2010), Li et al. (2011), and Kahsai et al. (2012).

Table 4.3. Results of the panel causality test

Dependent variable	Independent variables				
	Short Run				Long Run
	$\Delta LGDP$	$\Delta LEC$	$\Delta LLBR$	$\Delta LCPTL$	ECT
$\Delta LGDP$	-	0.036426 (0.9820)	0.461545 (0.7939)	7.291467 (0.0261)**	-0.007505 (0.0388)**
$\Delta LEC$	1.678305 (0.4321)	-	0.83376 (0.6591)	1.268163 (0.5304)	-0.063976 (0.0005)**
$\Delta LLBR$	1.114901 (0.5727)	1.077676 (0.5834)	-	1.008326 (0.6040)	-0.023798 (0.9810)
$\Delta LCPTL$	14.41235 (0.0007)**	0.317679 (0.317679)	0.009386 (0.9953)	-	-0.053255 (0.0167)**

Notes: Figures denote F-statistic values. P-values are in parentheses. ECT indicates the estimated error correction term. \*, \*\*, \*\*\* indicates statistical significance at the 10, 5 and 1 percent level, respectively.

The existence of a panel long-run cointegration relationship in the previous test has allowed this study to estimate the panel vector error correction model. Table 4.3 presents the results of the short-term and long-term causality tests for the group of all countries. In the short-run causality investigation, evidence of short-run causality running from electricity consumption to real GDP could not be found. In fact, none of the variables show significant impact on electricity consumption. Hence, short-term causality results indicate that there is no directional causality between electricity consumption and economic growth. However, the results indicate that real gross fixed capital formation have a statistical significant impact in the short run on real GDP at 5 percent level, and also significant at 5 percent level from GDP to real gross fixed capital formation. The finding of bidirectional causality confirms the neutral hypothesis between real gross fixed capital formation and GDP, implying that an increase in the real gross fixed capital formation may lead to the increase in GDP and vice versa. Overall, the panel causality tests indicate no existence of causality between electricity consumption and economic growth in the short run. These results mean that in the short run, electricity consumption and economic growth hold 'neutral hypothesis' which means they do not determine each other, and these outcomes are consistent with the results by Masih and Masih (1996) for Malaysia, Philippines, and Singapore; Soytaş and Sari (2003) for Indonesia.

Meanwhile, the long-run dynamics displayed by the error correction terms in the result suggests the presence of bi-directional causality between economic growth and electricity consumption. In addition, the error correction term in the GDP equation is statistically significant at 5 percent level, denoting a relatively slow speed of adjustment to long-term equilibrium which suggests that GDP and electricity consumption is adjusting towards long-term equilibrium at 0.75 percent and 6.4 percent, respectively. These findings confirm the feedback hypotheses, suggesting that changes in economic growth have an impact on changes

in electricity consumption and vice versa in the long-run. This means that energy conservation policies, particularly for electricity, will have impact on the overall performance of the economy in the long run. The findings of this study are consistent with the work of Asafu-Adjaye (2000) in revealing a bidirectional relationship between economic growth and energy consumption for Philippines and Thailand, and Yoo (2006) for Malaysia and Singapore.

## 5. Conclusions

For the group of all ASEAN countries, no causality or neutrality hypothesis was found in the short run. It means that neither electricity consumption nor economic growth influences each other in the short run. Therefore, any short-term policy established will not have a huge impact on the groups. Besides, it also indicates that there are other factors that drive the ASEAN economic growth for the short-term. However, a bidirectional or feedback hypothesis was discovered in the long run which implies that changes in economic growth will affect the electricity consumption and vice versa. The bi-directional causality between economic growth and electricity consumption also suggests that ASEAN growth heavily relies on the electricity consumption. Successively, as electricity consumption increases, the economic growth of ASEAN also increases in the long run. This outcome is expected since ASEAN as a whole, is in a growing phase and consume a lot of energy. Strong policy implications emerged for governments with regard to the implementation of electricity conservation policies. Therefore, there is a need for programmes or projects to expand the regional electricity production capacity.

Besides that, ASEAN as a whole needs to be more cautious in establishing and implementing energy policy, especially regarding electricity, as it may have a huge implication on the regional growth. The most important policy implication that can be drawn from this study is that adoption of any energy, especially electricity-based policy should be developed on a priority basis. It means that the sectors that contribute the most to the economic growth must be identified and any electricity development policy should be focused on those particular sectors. This is important in order to achieve rapid economic growth, and stop wasting time and energy resources on the non-profit sectors.

As a whole, the demand for electricity in ASEAN is growing at a very fast pace since it is required for economic growth and development. Looking at the electricity consumption trend, which I sexpected to be increased higher in the near future, there is a concern among ASEAN leaders and the world community that this region will be facing an energy crisis in the near future. Such crisis may affect the growth of ASEAN as it has been established by the outcomes of the estimation because energy has long-run implications in economic growth for this region as a whole. Therefore, the respective governments through the ASEAN community should establish an immediate and effective plan in order to avoid potential turmoil due to the energy crisis in the future. One of the approaches and might be the only answer to the energy-related problems is the development of renewable energy to generate electricity.

## References

- Adhikari, D., & Chen, Y. (2012). Energy Consumption and Economic Growth: A Panel Cointegration Analysis for Developing Countries. *Review of Economics & Finance*, 68-80.
- Adom, P.K. (2011). Electricity Consumption-Economic Growth Nexus: The Ghanaian Case. *International Journal of Energy Economics and Policy*, 1(1), 18-31.
- Apergis, N., & Payne, J.E. (2010). Energy Consumption and Growth in South America: Evidence from a Panel Error Correction Model. *Energy Economics*, 32, 1421-1426.

- Asafu-Adjaye, J. (2000). The Relationship between Energy Consumption, Energy Prices and Economic Growth: Time Series Evidence from Asian Developing Countries. *Energy Economics*, 22(6), 615–625.
- Baltagi, B.H. (2004). Panel Data: Theory and Applications. *Physica-Verlag Heidelberg, Germany*.
- Breitung, J. (2000): The Local Power of Some Unit Root Tests for Panel Data. B. Baltagi (ed.), *Nonstationary Panels, Panel Cointegration, and Dynamic Panels, Advances in Econometrics*, 15, 161-178.
- Chaudhry, I.S., Safdar, N., & Farooq, F. (2012). Energy Consumption and Economic Growth: Empirical Evidence from Pakistan. *Pakistan Journal of Social Sciences*, 32(2), 371-382.
- Ciarreta, A. & Zarraga, A. (2010) Economic Growth-Electricity Consumption Causality in 12 European Countries: A Dynamic Panel Data Approach. *Energy Policy*, 38, 3790-3796.
- Dantama, Y. I., Abdullahi, Y. Z., & Inuwa, N. (2011). Energy Consumption - Economic Growth Nexus in Nigeria: An Empirical Assessment Based on ARDL Bound Test Approach. *European Scientific Journal June Edition*, 8(12), 141-157.
- Dlamini, J., Mehmet, B., Rangan, G., & Roula, I. (2013). Revisiting the Causality between Electricity Consumption and Economic Growth in South Africa: A Bootstrap Rolling-Window Approach. *University of Pretoria Department of Economics Working Paper Series 2013-30 July 2013*.
- Engle, R.F., & Granger, C.W.J. (1987). Cointegration and Error Correction: Representation, Estimation and Testing, *Econometrica*, 55, 251-276.
- EIA (2013). International Energy Outlook 2013. *U.S. Energy Information Administration*.
- Ghali, K. H., & El-Sakka, M. I. T. (2004). Energy Use and Output Growth in Canada: A Multivariate Cointegration Analysis. *Energy Economics*, 26, 225-238.
- Gyngell, A. (1983). Looking Outwards: Asean's External Relations. Alison Broinowski (Ed.). *Understanding ASEAN*. London: Macmillan Press Ltd.
- Huang, B., Hwang, M., & Yang, C. (2008). Causal Relationship between Energy Consumption and GDP Growth Revisited: A Dynamic Panel Data Approach. *Ecological Economics*, 67(1), 41–54.
- IEA (2015). World Energy Outlook 2015. International Energy Agency, Paris, France.
- Im, K.S., Pesaran, M.H., & Shin, Y. (2003). Testing for Unit Roots in Heterogeneous Panels. *Journal of Econometrics*, 115(1), 53-74.
- Imran, K., & Siddiqui, M.M. (2010). Energy consumption and economic growth: A case study of three SAARC countries, *European Journal of Social Sciences*, 16(2), 206-213.
- Jumbe C.B.L. (2004). Cointegration and Causality between Electricity Consumption and GDP: Empirical Evidence from Malawi. *Energy Economics*, 26(1), 61-68.
- Kahsai, M.S., Nondo, C., Schaeffer, P. V., & Gebremedhin, T.G. (2012). Income level and the energy consumption-GDP nexus: Evidence from Sub-Saharan Africa, *Energy Economics*, 34(3), 739-746.
- Kraft, J., & Kraft, A. (1978). On the Relationship between Energy and GNP. *Journal of Energy and Development* 3, 401–403.
- Kurlantzick, J. (2012). ASEAN's Future and Asian Integration. International Institutions and Global Governance.

- Lau, E., Chye X.H., & Choong, C.K. (2011). Energy-Growth Causality: A Panel Analysis. *International Conference on Applied Economics – ICOAE*, 355-361.
- Levin, A., Lin, C.F., & Chu, C. (2002). Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties. *Journal of Econometrics*, 108 (1), 1-24..
- Li, F., Dong, S., Li, X., Liang, Q., & Yang, W. (2011). Energy Consumption-Economic Growth Relationship and Carbon Dioxide Emissions in China. *Energy Policy*, 39(2), 568-574.
- Lütkepohl, H. (1982). Non-causality due to Omitted Variables. *Journal of Econometrics*, 19, 367-378.
- Mahran, H. A. (2012). Financial Intermediation and Economic Growth in Saudi Arabia: An Empirical Analysis, 1968-2010, *Modern Economy*, 3, 626-640.
- Masih, A. M. M., & Masih, R. (1996). Energy Consumption, Real Income and Temporal Causality: Results from A Multi-Country Study Based On Cointegration and Error correction Modelling Techniques. *Energy Economics*, 18, 165-183.
- Masuduzzaman, M. (2013). Electricity Consumption and Economic Growth in Bangladesh: Cointegration and Causality Analysis. *Research Study Series No.-FDRS 02*, 31-48.
- Mishra, V., Sharma, S., & Smyth, R. (2009). Are Fluctuations in Energy Consumption Per Capita Transitory? Evidence from a Panel of Pacific Island Countries, *Energy Policy*, 37(6), 2318-2326..
- Narayan, P. K., & Smyth, R. (2008). Energy Consumption and Real GDP in G7 Countries: New Evidence from Panel Cointegration with Structural Breaks. *Energy Economics*, 30(5), 2331–2341.
- Olayeni, O. R. (2012). Energy Consumption and Economic Growth in Sub-Saharan Africa: An Asymmetric Cointegration Analysis. *International Economics*, 129, 99-118.
- Ozturk, I., Aslan, A., & Kalyoncu, H. (2010). Energy Consumption and Economic Growth Relationship: Evidence from Panel Data for Low and Middle Income Countries. *Energy Policy*, 38(8), 4422 – 4428.
- Payne, J.E., & Taylor, J.P. (2010). Nuclear Energy Consumption and Economic Growth in the US: An Empirical Note. *Energy Sources, Economics, Planning, and Policy*, 5, 301–307.
- Pesaran, M.H., & Smith, R.P. (1995). Estimating Long-run Relationships from Dynamic Heterogeneous Panels. *Journal of Econometrics*, 68, 79–113.
- Pesaran, M. H., Shin, Y., & Smith, R. (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association*, 94, 621-634.
- Rafindadi, A. A., & Yusof, Z. (2013). An Application of Panel ARDL in Analysing the Dynamics of Financial Development and Economic Growth in 38 Sub-Saharan African Continents. *Proceeding, Kuala Lumpur International Business, Economics and Law Conference Vol. 2, ISBN 978-967-11350-2-0*, 118-135.
- Rosenberg, N. (1998). The Role of Electricity in Industrial Development. *The Energy Journal* 19(2), 7-24.
- Soytas, U., & Sari, R. (2009). Energy Consumption, Economic Growth and Carbon Emissions: Challenges faced by an EU Candidate Member. *Ecological Economics*, 68, 1667-1675.
- To, H., Wijeweera, A., & Charles, M.B. (2012). Energy Consumption and Economic Growth – The Case of Australia. *Business School, Southern Cross University*.
- Yoo, S.H. (2006). The Causal Relationship between Electricity Consumption and Economic Growth in the ASEAN Countries. *Energy Policy*, 34, 3573-3582.